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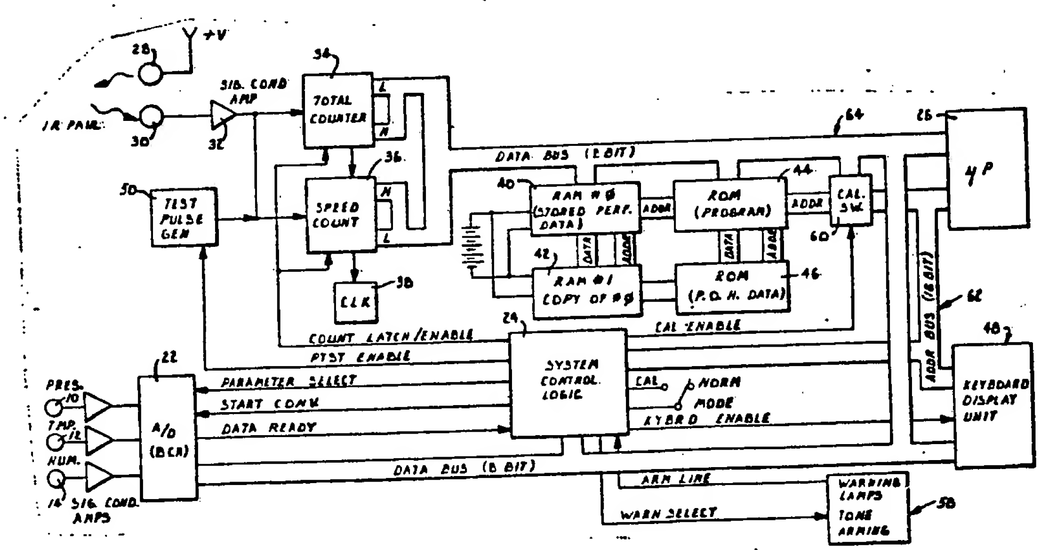

(57) Abstract

A method and apparatus for tymely advising the crew or an aircraft during the ground roll portion of takeoff of the relationship between actual velocity attained and computed velocity desired for safe takeoff performance. Means (52) are provided for the crew to enter and store variable runway distances and aircraft load data and for measuring and storing existing meteorological data. Distance and velocity data is measured from the aircraft wheel (70) rotations by infrared light reflections and this information is used with the stored data and predetermined aircraft performance data to compute the relationship between attained velocity and desired velocity for safe takeoff within the limits prescribed by the particular runway. Signals indicting the computed relationships are given the crew by flashing and color coded visible light signals and by an audible warning tone (58). The apparatus includes features (60) to enable the crew to calibrate the apparatus to compensate for variations in wheel diameters which would affect distance measurements.

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CRITICAL RUNWAY MARGIN WARNING SYSTEM

This invention pertains to warning systems and more particularly to a method and apparatus for advising a pilot of an aircraft before the point of no return in a takeoff as to the likelihood of successful takeoff within the limits of available runway length.

It is well known that takeoff is a very critical maneuver in the operation of an aircraft. A number of different variables can each materially affect aircraft performance and if each of these is not carefully considered, the pilot may not be able to achieve lift-off early enough in the maneuver to safely clear obstacles in the flight path.

The pilot can obtain some indication of aircraft performance by air speed indicator instruments in the cockpit. However, by the time the pilot becomes aware that the velocity required for successful takeoff under existing conditions may not be attained, the aircraft may have proceeded so far down the runway that insufficient runway length remains in which to safely stop the airplane.

The problem is exacerbated by the relative complexity in computing expected performance in view of the rather substantial variables which are involved. Current practice requires that the pilot compute safe stopping distance and takeoff velocities in order to determine that the critical velocity can be achieved safely within the

limits imposed by available runway length and under ambient pressure, temperature and humidity conditions. Superimposed on these variables are the performance characteristics which apply to the particular airplane involved.

While charts and formulae are available to assist and enable the pilot to perform the necessary calculations, it is well known that they frequently are not carried out. Even when the calculations are made, they are highly subject to error.

The consequences from neglect or miscalculation, which often is not detected until there is no margin for error, are often dire. A crash during takeoff is usually destructive to the aircraft and frequently results in death to some or all of the crew and passengers. There is, therefore, a need for a relatively simple and effective means to timely warn the pilot if safe takeoff under existing conditions does not appear likely.

Accordingly, it is a primary object of the present invention to provide a method, and apparatus for carrying the method into effect, of advising the crew during the ground roll portion of the takeoff of the attained velocity performance in comparison to the ideal performance necessary for safe takeoff under existing conditions including available runway length.

It is another very important object of the present invention to provide such crew advice sufficiently early in the takeoff run as to enable the pilot to abort the takeoff attempt while remaining runway distance available exceeds the safe stopping distance for the airplane.

A further important object of the invention is to provide a quick and easy means for an aircraft crew to compute the velocity which should ideally be attained at any distance

along the ground roll for successful takeoff of the aircraft within predetermined distance limitations and under existing weather and load conditions.

Yet another object of the present invention is to provide means for an aircraft crew to quickly and easily determine the runway margin of safety factor which is involved in a prospective takeoff on a runway of given length and under existing conditions.

A further object of this invention is to provide calculated relative performance advice to the crew in advance of the point of no return in a takeoff run by a relatively simple and unobtrusive system utilizing contrasting visual and audible signals and with equipment which can be easily added to the conventional instrumentation available in the aircraft cockpit.

Still another object of this present invention is to provide a simple, inexpensive and accurate way to obtain necessary distance and velocity measurements utilizing the revolutions of an aircraft ground support wheel and energy reflections from the wheel which are not adversely affected by ambient light conditions.

These and other important aims and objectives of this invention will be further explained or will become apparent to those skilled in the art from the following claims and explanation of the drawings in which:

Figure 1 is a fragmentary, side elevational view of an aircraft ground support wheel illustrating the installation of an infrared pair for speed and distance measurements;

Fig. 2 is a front elevational view on an enlarged scale of a keyboard display unit of the type contemplated for use in carrying out the principles of this invention;

Fig. 3 is a diagram illustrating a typical velocity distance curve for an aircraft takeoff;

Fig. 4 is a schematic diagram illustrating system apparatus for carrying out the principles of this invention; and

Fig. 5 is a diagram illustrating signficant zones of the runway and the warning signals given to the crew as the respective zones are reached.

The system of the invention provides a fast and accurate means of calculating the therotical takeoff curve or "standard" for an airplane, accounting for atmospheric conditions and actual weight, without the laborious task of consulting tables, graphs and aircraft instruments to arrive at the calculations. The system also automatically translates the calculations into single, meaningful criteria regarding the adequacy of runway length actually available and automatically records the data for future reference. The actual takeoff performance of the airplane is monitored and automatically compared with the recorded standard and a system of visual lights and audible tones provide the pilot with advisory information to enable him to abort the takeoff, if necessary, while the distance remaining on the runway equals or exceeds the stopping distance for the particular aircraft.

Apparatus for carrying the invention into effect is illustrated schematically in Fig. 4 of the drawing and includes transducers 10, 12 and 14 for automatically measuring the ambient pressure, temperature and humidity conditions and converting these measured meteorological quantities to electrical signals proportional to the level of the measured physical quantities. Each of the transducers is connected to its respective signal conditioner 16, 18 and 20 respectively. Each conditioner

converts its respective electrical signal to one acceptable for input to an analog-digital converter 22. Converter 22 converts the analog or continuous signal from the signal conditioning circuit to a digital or discrete code.

This coded information is, in turn, fed to the system control logic 24. The latter comprises a collection of circuits which provides an interface between a microprocessor 26 and the various other circuits in the system which require access to the miroprocessor. Functions provided by the system control logic 24 include the decoding of processor address information, latching (temporary holding) of data from other circuits to the microprocessor and from the microprocessor to these circuits, providing electrical signals to a display to be hereinafter described, and the timing for various circuit elements. In addition, the system control logic 24 provides signals to the crew warning panel on command of the microprocessor, and provides the electrical switching necessary to implement an optional self-test function to check the operation of the system components, if desired, without necessity for actual aircraft movement.

It should be pointed out at this juncture that the lines shown on Fig. 4 are intended to represent flow lines for the passage of data or signals through the system to the various essential elements and do not necessarily represent electrical connections. In some cases, the lines represent a single electrical connection and in others the lines may represent a plurality of electrical connectors. The data bus lines are illustrated as a broad band between a pair of parallel lines with the presently preferred capacity of the respective buses indicated on each bus.

An infrared "pair" consisting of an emitter 28 and a

detector 30 are mounted on the aircraft adjacent a ground supporting wheel as will be presently more fully described. Detector 30 is connected to a signal conditioner 32 to amplify the level of electrical pulses produced by the detector and to provide a means to insure uniform height pulses with a minimum of distortion. The signal from conditioner 32 is fed to a pair of counters 34 and 36 respectively. Counters 34 and 36 are circuits which, given an input signal in the form of pulses, produce a digitally coded output corresponding to the number of input pulses in a given unit of time.

Counter 34 is of a type which counts the total number of signals from the infrared detector 30. It is contemplated that counter 34 may be reset as desired so that the total number of pulses from detector 30 may be counted from a selectable point of beginning.

Counter 36 has at its input an external clock or pulse generator 38, designed to very accurately produce pulses of a known frequency. These pulses are counted over an interval of time corresponding to the interval between two successive pulses from detector 30 for the purpose of measuring velocity. The digitally coded output of counter 36 corresponds to the period of the pulses from detector 30 which, as will be subsequently pointed out, also corresponds to the period of wheel rotation and is inversely proportional to the speed of the wheel of the aircraft.

A test pulse generator 40 is illustrated in Fig. 5 and serves to provide a signal to counters 34 and 36 on command of the microprocessor to simulate the pulses normally generated by the IR pair 28 and 30. In this way, counters 34 and 36 may be tested for accuracy prior to actual operation of the aircraft. Test pulse generator 50 serves as a safety feature for testing the integrity of

the unit without the necessity for actual aircraft movement.

Included in the system are a pair of random access memories 40 and 42. Memory 42 stores a copy of the data stored in memory 40 which data is the actual performance data of the aircraft during a test run. This memory allows the pilot to store takeoff and braking distance data for his aircraft for comparison later during actual operation of the warning device. This data is modified by air density, aircraft weight and the like in actual operation. Since two copies of the data are stored in memories 40 and 42, the data in the respective memories may be compared during self-test of the system. The random access memory (RAM) is of the "non-volatile" type and remains stored unless changed by a recalibration of the system.

A pair of "read only" memories (ROM) 44 and 46 store two types of data. The first type of data stored in these memories is performance data pertaining to the particular aircraft. Such data is made available by the aircraft manufacturer and is published, for example, in the pilot's Operating Handbook. Performance data for takeoff distance, stopping distance and the like is calculated from this data and from the actual recorded data stored in memories 40 and 42 mentioned above. The second type of data stored in memories 44 and 46 is program data. This data provides the instructions in a sequential manner to the microprocessor enabling it to perform those tasks inherent to the operation of the total system. As in the case of memories 40 and 42, the two ROMs 44 and 46 permit two copies of this ROM data to be stored and compared for accuracy in a self-test of the operation of the system.

A keyboard display unit 48 functions as an interface between the operator of the system and the computer. As illustrated more particularly in Fig. 2 of the drawing,

unit 48 includes a housing 50, a keyboard 52 and a liquid crystal display 54 which can display numeric data. Aircraft weight, runway length and other parameters may be entered into the system through the keyboard. Density altitude, takeoff distance, runway margin distance, and the like as calculated by the microprocessor are available to the crew at the display 54.

In the presently preferred embodiment, unit 48 is of a size that it may be readily installed in the cockpit of an aircraft preferably in the vicinity of the lower edge of the instrument panel and/or the center console, within reach of either the pilot or co-pilot. The unit is readily removable from its "stowed" position and is operably coupled into the system by a flexible electric cord 56 having sufficient length that it can be handheld by either crew member for easy data input and reading. Those functions requiring pilot input, such as takeoff weight (WT), wind component down the runway (WD), and runway length available (R/W) are all coupled with appropriately designated keys on the keyboard all having the same color. Functions such as density altitude (D/A) and runway margin (R/M) may be accessed by respectively designated keys of a distinctive different color to remind the operator that the "read out" of these functions is immediately available from the system and will be displayed on display 54 upon depressing of these designated keys.

The crew warning display is designated by the numeral 58 in Fig. 4 of the drawing. This unit may take any of a variety of possible forms but is presently preferred to include a plurality of lamps and an audible alarm necessary to indicate the status of a takeoff roll to the pilot or other members of the crew. Lights of different colors such as green and amber, each capable of pulsing or a steady glow, are provided. The audible signal is provided by a tone emitter.

Warning display unit 58 is controlled by the microprocessor 26 through the system control logic. This unit also contains an "arming" switch which, when closed, resets the counters 34 and 36 and alerts the microprocessor to enter the appropriate mode for runway distance and speed monitoring. In its present configuration, the armed condition of the system is indicated by a small lamp (not shown) on the unit.

Inasmuch as the speed and distance measurements essential to the operation of the system are taken from the rotation of one of the wheels of the aircraft, it is desirable that the system be capable of ready calibration to accommodate for any variations which may be encountered in the actual diameter of the aircraft wheel. For example, it will be readily understood that the actual diameter of an aircraft supporting wheel may vary depending upon differences in the inflation pressure of the tire. Further, there may be variations in the diameters of different tires used with the aircraft. A calibration switch 60 is provided in the system to effect such calibration. When the calibration mode is entered by the operator, the microprocessor provides a correction factor after distance measurements are made by the system while the aircraft is actually moved over a measured course. This correction factor is shown on the keyboard display 54 and may be set through switch 60 to calibrate the system in accordance with the distance actually traversed by the aircraft during each wheel revolution.

Microprocessor 26 is the "master controller" of the system. In conjunction with a program, or set of sequential instructions stored in ROMs 44 and 46, the microprocessor performs the necessary mathematical operations, selects the appropriate data source (transducers, counters, and the like), sends data to the LCD unit 54 and activates the appropriate signals for

operation of the overall device, sometimes acting through the system control logic. Microprocessor 26 contains two major buses or groups of electrical lines. The address bus 62 is used to select a data source or device to accept data output. It contains 16 electrical lines. The data bus 64 is used for the transfer of numeric, digitally coded data from and to the microprocessor from and to the device or unit selected by the address bus 62. Data bus 64 includes eight lines. All digitally coded numeric data to or from the microprocessor and other units in the system is carried on these lines.

Referring now to Fig. 1 of the drawing, the infrared emitter 28 and its associated infrared detector 30 are both mounted on a bracket 66 carried by the landing gear 68 of an aircraft ground engaging and supporting member 70. Member 70 includes a pneumatic tire 72 mounted on a wheel 74 which is, in turn, journalled on landing gear strut 76.

In the operation of the system of this invention it is important that accurate distance and speed measurements be available for critical calculations necessary to the system. It has been found that such measurements may be readily and accurately obtained by monitoring the number of wheel rotations. The number of rotations from a given point of beginning are counted and totaled to determine the distance measurement. Speed may be calculated by determining the number of discrete divisions of time which elapse during each wheel revolution.

A simple and expedient means for accurately sensing each wheel revolution involves mounting an energy reflecting element at a given point on the wheel, transmitting energy toward the wheel on the path of movement of the reflective element and recording the energy reflected from the element each time it reaches a given location on its circular path of travel. To this end, a reflective strip

of material 78 is fixedly secured to wheel 74 so that it rotates past the IR pair 28 and 30 as the tire rolls along the runway. IR energy is constantly transmitted by emitter 28 against the wheel but this energy is reflected to detector 30 only at the time the wheel completes a revolution bringing element 78 into opposed relationship with detector 30. It will, of course, be apparent that bracket 66 is configured so that the IR pair is held in spaced apart, offset relationship from wheel 74. The number of pulses produced by detector 30 as a consequence of the IR energy reflected thereto by element 78 are a function of the number of revolutions of the wheel.

Infrared energy has been selected for the purpose of effecting distance and speed measurements in the system because such energy is not adversely effected by ambient light. Thus, the measurements may be made equally as well in daylight or in darkness and will not be affected should beams of visible light be directed in the vicinity of the wheel.

Figure 5 of the drawing may be referred to for an understanding of the operation of the system including the utilization of the components of the system heretofore described. It may be assumed that data which is particular and characteristic of the performance of the aircraft during takeoff is stored in the memories as heretofore described. Ambient meterorology data is sensed by transducers 10, 12 and 14 and is stored in the data base. The pilot enters into the data base through keyboard display unit 48 critical data such as the weight or loading of the aircraft, the wind component down the runway and the runway length available for the takeoff. This data is sufficient, assuming predetermined or predicted aircraft performance, for computing a predicted velocity at any given distance along the runway. A typical curve illustrating the expected velocity at any

given runway distance is illustrated in Fig. 3 of the drawing.

In accordance with the current state of the art, such calculations are extremely awkward and are seldom made to the extent required for reasonable reliability. With the system of this invention the calculations are readily and almost instantaneously made by the microprocessor and the results of the calculations can be called up by the operator to the display 54 of unit 48.

The system is put into operation when a member of the crew, usually the pilot, arms the system by pressing an appropriately designated key on the keyboard display unit 48 operably connected to the system control logic and the other components as hereinbefore described. This results in the setting of the counters 34 and 36 to zero and energizes the functioning components including the transducers to automatically sense and store the ambient pressure, temperature and humidity measurements.

The operator enters on the keyboard digits corresponding to the prevailing wind component and also the length of the runway available for the takeoff maneuver. Such data is readily available to the pilot if the takeoff is from an established airport. In the event that the takeoff should be from a runway of unknown length, as from an emergency landing strip, the pilot can actually measure the distance of the runway by taxiing the aircraft the entire length of the runway and obtaining the readout of the distance as measured by counter 34.

This distance is entered into the data stored in the system and the pilot may then rearm the system to set the counters to zero as heretofore described. Another entry is made through keyboard unit 48 corresponding to the actual loading of the aircraft. This data is also stored in the system.

The system is programmed to automatically begin conveying information to the crew at a point along the runway bearing a relationship to the stopping distance for the aircraft. This stopping distance is a variable depending upon the momentum of the plane during the takeoff run. It is presently considered that an appropriate point for the initiation of signals to the crew is when the aircraft reaches 80% of the runway distance less the total of the stopping distance together with runway distance which may exist in excess of the combined stopping distance and runway distance computed to reach takeoff velocity. This may be expressed by the formula .8(LR-ds-de) as illustrated in the Fig. 5 diagram, subsequently to be more fully explained.

The 80% factor is arbitrary and this factor could be changed by building some other appropriate factor into the system if desired. However, it is considered necessary that the system initiate automatic signals to the crew at some point in advance of the aircraft actually reaching the point where only the safe stopping distance for the aircraft remains.

The aforementioned diagram illustrating the points along the runway at which certain events take place in the use of the system of this invention is set forth in Fig. 5 of the drawing. The total available runway length is indicated LR in the diagram. The computed runway length expected to be required for the aircraft to reach takeoff velocity under existing conditions from the data stored in the date base of the system is designated in the diagram as dr. The distance calculated to stop the aircraft under existing conditions at takeoff velocity is measured from the extreme far end of the runway and is designated in the diagram ds. The difference between dr and ds is the excess runway or runway distance which may be added to dr to represent the total runway distance available to reach takeoff velocity with sufficient runway

remaining to safely stop the airplane in the event that takeoff velocity is not reached within the distance embraced by dr + de.

It will, of course, be apparent that the computation to determine the respective runway distances are made automatically by the system and the value of each computation can be called to the keyboard display as desired by the pilot. In the event that the available runway length should actually be less than dr + ds, the value of the marginal runway distance (de) is a negative value. The computer is programmed with a logic which gives priority to the stopping distance. Thus, the keyboard display unit will forewarn the pilot of this condition by displaying runway margin on display 54 with a negative sign and a flashing mode. Should the pilot proceed with the takeoff under this condition, an audible signal and the extinguishment of the visual signals as will be more fully described hereinafter will indicate to the pilot the point along the takeoff run where the runway distance remaining is equal to the predicted stopping distance (ds) for the aircraft.

Assuming, however, that the runway used for the takeoff provides for excess runway (de), the apparatus of the system sends a visual signal to the pilot when the measured total distance traversed by the airplane in the ground roll portion of the takeoff as measured by counter 34 reaches a predetermined selected point along the runway such as point 80 in Fig. 5 of the drawing representing 80% of the distance dr. As heretofore been explained, had the pilot selected some other point, the visual signal would automatically be sent to the pilot at such other selected point. The visual signal includes a pair of lights, one green and one amber which are operably connected with and operate on signal input from the microprocessor 26. These lights are preferably located in the edge or in the vicinity of the glare shield which is

normally positioned on top of the instrument panel and in front of the pilot. This position for the lights is chosen so that they may be observed by the pilot without the necessity for a shift of vision from the runway.

Either the green or the amber light begins pulsing at point 80. If the actual measured performance of the aircraft during the ground roll portion of the takeoff at point 80 exceeds the velocity expected from the data stored in the system at this point, the green light begins pulsing at this point and the amber light is unenergized. A pulsing frequency of from one to ten hertz is considered desirable for the lights. On the other hand, if the measured velocity at point 80 is below that which is expected under ambient conditions by the computation made from the stored data in the system, the green light remains unenergized at this point and the amber light begins pulsing. This visually advises the pilot whether or not the actual aircraft performance to this point equals the hypothetical ideal performance required for reaching takeoff velocity at the expected point on the runway and it also advises him whether or not the actual performance has been greater or less than ideal. Certainly, if the amber light is pulsed, the pilot can take remedial measures in an attempt to increase aircraft performance to achieve takeoff velocity at or about the expected point along the runway.

When the point on the runway where takeoff velocity has been calculated to be expected to be achieved is reached by the aircraft (at the end of dr), the system automatically changes the visual signal to that of a steady amber light if takeoff velocity has not yet been achieved. This amber light continues through the distance designated de on the diagram. Throughout the portion of the takeoff roll when the steady amber signal is displayed to the pilot, he is advised that takeoff velocity has not yet been achieved and he has exceeded the

distance along the runway during which it was expected that takeoff velocity would have been achieved. During this period, the pilot is warned by the steady amber light that it may be necessary to abort the takeoff.

If, however, takeoff velocity is achieved and the takeoff is accomplished before reaching the extreme end of the distance designated de, the system is automatically disarmed and no further warning is necessary. On the other hand, if the total distance measured from the beginning of the takeoff roll passes the point corresponding to the final end of distance de without takeoff having been achieved, all lights are automatically extinguished and an audible tone is emitted by device 58. The audible tone may be generated by any suitable sound generating device (not shown). The pilot is warned by the tone that he should begin stopping the takeoff attempt immediately so that the plane can be stopped before the end of the runway is reached. The decision as to whether or not the pilot shall take such action at this time remains, of course, with the pilot. It is possible that the pilot will determine that he is so near to reaching takeoff velocity that it can be safely achieved if the effort is continued. On the other hand, the pilot will be aware at this point that the actual performance of the aircraft during the takeoff attempt to this point has not reached takeoff velocity and he can still stop the airplane before reaching the extreme end of the runway. He may, and probably will, determine at this point to cease the takeoff attempt and bring the aircraft to a safe stop within the limits of the runway.

It will now be apparent to those skilled in the art that the method and apparatus of this invention offers to a crew of an aircraft a convenient and easily operated means for obtaining timely advice during takeoff of the critical relationship between remaining runway distance and attained velocity in comparison to required

performance under existing conditions. This advice is obtained substantially automatically and without the requirement for complicated and time consuming manual calculations. Further, the predetermined system of a combination of visual and audible signals updates the advice to the pilot during a critical portion of the takeoff so that he is constantly aware of the actual performance in comparison to the hypothetical performance and also of the location of the aircraft relative to key runway distances so that he may take appropriate safety action before the point of no return is reached. When properly used, the system is an important safety tool to aid a pilot during the critical takeoff maneuver.

1. A method of timely advising the crew of an aircrft during takeoff of the critical relationship between remaining runway distance and attained velocity in comparison to required performance under existing conditions, said method comprising: storing predetermined aircraft takeoff performance and weight data in a data base; storing existing meteorological data in said data base; storing runway distance available for takeoff in said data base; measuring the velocity of the aircraft during the ground roll portion of takeoff; measuring the distance traveled by the aircraft during the ground roll portion; comparing the measured aircraft velocity with a hypothetical desired velocity computed from said stored performance weight and metecrological data and from said distance traveled measurement; and signalling the crew prior to the aircraft reacing a predetermined runway location short of the full runway distance to indicate said comparison.

2. The method of claim 1, wherein the step of signalling the crew takes place prior to the aircraft reaching a point on the runway where the stopping distance for the aircraft at attained velocity under existing conditions equals the available runway distance less the distance traveled by the aircraft.

3. The method of claim 2, wherein the signalling step occurs prior to the aircraft reaching a point on the runway which corresponds with the distance expected to be traveled by the aircraft in reaching the hypothetical desired lift-off velocity under existing conditions as computed from said stored data.

4. The method of claim 1, wherein said signalling step includes the transmission of a visible signal.

5. The method of claim 1, wherein said signalling step includes the transmission of an audible signal.

6. The method of claim 1, wherein said signalling step includes the transmission of both audible and visual signals.

7. The method of claim 1, wherein said distance measuring step includes: transmitting a reflectible signal toward a rotatable member of known circumference secured to the aircraft and operably engaging the runway for rotation thereby as the aircraft travels along the runway; reflecting said signal from said member at least once during each revolution of the member; receiving said reflected signals; and counting the signals received whereby to determine the number of member revolutions and thus distance traveled by the aircraft.

8. The method of claim 7, wherein is included the step of establishing a distinct time interval of predetermined duration, and wherein the step of measuring said aircraft velocity includes the step of counting the number of reflected signals received within said time interval.

9. The invention of claim 7, wherein said reflectable signal is an infrared emission.

10. The invention of claim 1, wherein is included the steps of: measuring the atmospheric pressure, measuring the ambient temperature, measuring the atmospheric humidity, and wherein said step of storing existing meteorological data includes the storing of the pressure, temperature and humidity measurements.

11. Apparatus for timely advising the crew of an aircraft during takeoff of the critical relationship between remaining runway distance and attained velocity in comparison to required performance under existing conditions, said apparatus comprising: means for storing predetermined aircraft performance data, existing meteorological data, load weight and available runway

distance in a data base; means for measuring the attained velocity of the aircraft during the ground roll portion of the takeoff; means for measuring the distance traveled by the aircraft during the ground roll portion of the takeoff from a predetermined point on the runway; means for computing a hypothetical desired velocity under existing conditions from data in said data base for a plurality of locations along the runway; means for comparing the attained aircraft velocity to the computed desired velocity; and means for signalling the crew to indicate the comparison.

12. Apparatus as set forth in claim 11, wherein said distance measuring means includes means for directing light toward an aircraft support wheel, means for receiving reflected light from the wheel, means on the wheel for reflecting said light to the receiving means during a predetermined portion of each revolution of the wheel, and means for counting the reflections to determine the number of wheel revolutions.

13. Apparatus as set forth in claim 12, wherein said velocity measuring means includes means for sensing a predetermined time interval, and means for counting the number of light reflections received from the wheel withing said time interval.

14. Apparatus as set forth in claim 12, wherein said light directing means includes an infrared light emitter.

15. Apparatus as set forth in claim 11, wherein said signalling means includes means for transmitting visible light.

16. Apparatus as set forth in claim 15, wherein said transmitting means includes means for selectively dislaying a plurality of lights of different colors, and means for causing the flashing of at least one of said

lights.

17. Apparatus as set forth in claim 11, wherein said signalling means includes means for transmitting an audible signal.

18. Apparatus as set forth in claim 12, wherein is included calibrating means operably coupled with said measuring means and with said computing means to compensate for variations in the measured distances as a result of variations in the circumference of said member.

AMENDED CLAIMS

[received by the International Bureau on 26 February 1985 (26.02.85); original claims 4,6,9 and 14 cancelled and remaining claims renumbered; original claims 1,7,10,11,12,13 amended (4 pages follow)]

1. A method of timely advising the crew of an aircraft during takeoff of the critical relationship between remaining runway distance and attained velocity in comparison to required performance under existing conditions, said method comprising: storing predetermined characteristic aircraft takeoff performance and weight data in a data base on board the aircraft; storing existing meteorological data in said data base, the stored characteristic takeoff performance, weight and meteorological data being sufficient for computing the hypothetical velocities expected to be attained by the aircraft at all points throughout the takeoff run of the aircraft; storing runway distance available for takeoff in said data base; continuously measuring the velocity of the aircraft during the ground roll portion of a takeoff run; continuously measuring the distance traveled by the aircraft during the ground roll portion of said takeoff run; continuously comparing the measured aircraft velocity with a hypothetical desired velocity computed from said stored performance, weight and meteorological data and from said distance traveled measurement; and signalling the crew by a predetermined coded light illumination in the cockpit prior to the aircraft reaching a predetermined runway location short of the full runway distance when the result of said comparison reveals a predetermined quantitative difference between the actual and the predicted velocities.

2. The method of claim 1, wherein the step of signalling the crew takes place prior to the aircraft reaching a point on the runway where the stopping distance for the aircraft at attained velocity under existing conditions equals the available runway distance less the distance traveled by the aircraft.

3. The method of claim 2, wherein the signalling step occurs prior to the aircraft reaching a point on the runway which corresponds with the distance expected to be

traveled by the aircraft in reaching the hypothetical desired lift-off velocity under existing conditions as computed from said stored data.

4. The method of claim 1, wherein said signalling step includes the transmission of an audible signal.

5. The method of claim 1, wherein said distance measuring step includes: transmitting a reflectible infra red signal toward a rotatable member of known circumference secured to the aircraft and operably engaging the runway for rotation thereby as the aircraft travels along the runway; reflecting said signal from said member at least once during each revolution of the member; receiving said reflected signals; and counting the signals received whereby to determine the number of member revolutions and thus distance traveled by the aircraft.

6. The method of claim 5, wherein is included the step of establishing a distinct time interval of predetermined duration, and wherein the step of measuring said aircraft velocity includes the step of counting the number of reflected signals received within said time interval.

7. The invention of claim 1, wherein is included the steps of: from on board the aircraft, respectively, measuring the atmospheric pressure, the ambient temperature, and measuring the atmospheric humidity, and wherein said step of storing existing meteorological data includes the storing of the pressure, temperature and humidity measurements.

8. Apparatus for timely advising the crew of an aircraft during takeoff of the critical relationship between remaining runway distance and attained velocity in comparison to required performance under existing conditions, said apparatus comprising: means for storing

predetermined aircraft performance data, existing meteorological data, load weight and available runway distance in a data base; means for continuously measuring the attained velocity of the aircraft during the ground roll portion of the takeoff; means for continuously measuring the distance traveled by the aircraft during the ground roll portion of the takeoff from a predetermined point on the runway; means for continuously computing a hypothetical desired velocity under existing conditions during the takeoff run from data in said data base and from the distance traveled measurement; means for continuously comparing the attained aircraft velocity during the takeoff run to the computed desired velocity; and means for signalling the crew when the quantitative difference between the actual and predicted velocities reach a predetermined value.

9. Apparatus as set forth in claim 8, wherein said distance measuring means includes means for directing infra red light toward an aircraft support wheel, means for receiving reflected light from the wheel, means on the wheel for reflecting said light to the receiving means during a predetermined portion of each revolution of the wheel, and means for counting the reflections to determine the number of wheel revolutions.

10. Apparatus as set forth in claim 9, wherein said velocity measuring means includes means for sensing a predetermined time interval, and means for counting the number of light reflections received from the wheel within said time interval.

11. Apparatus as set forth in claim 8, wherein said signalling means includes means for transmitting visible light.

12. Apparatus as set forth in claim 11, wherein said transmitting means includes means for selectively

dislaying a plurality of lights of different colors, and means for causing the flashing of at least one of said lights.

13. Apparatus as set forth in claim 8, wherein said signalling means includes means for transmitting an audible signal.

14. Apparatus as set forth in claim 9, wherein is included calibrating means operably coupled with said distance measuring means and with said computing means to compensate for variations in the measured distances as a result of variations in the circumference of said member.

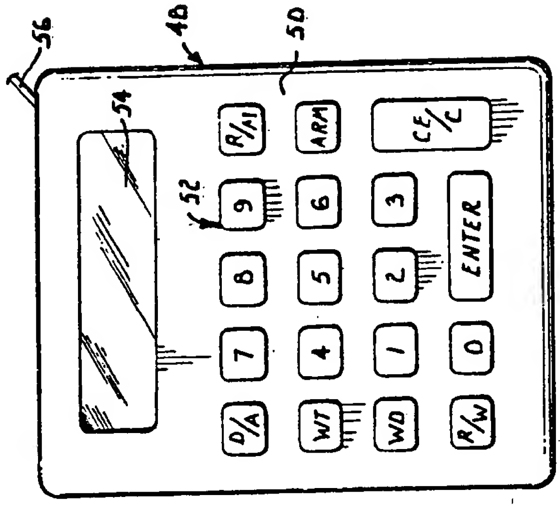

Fig. 2.

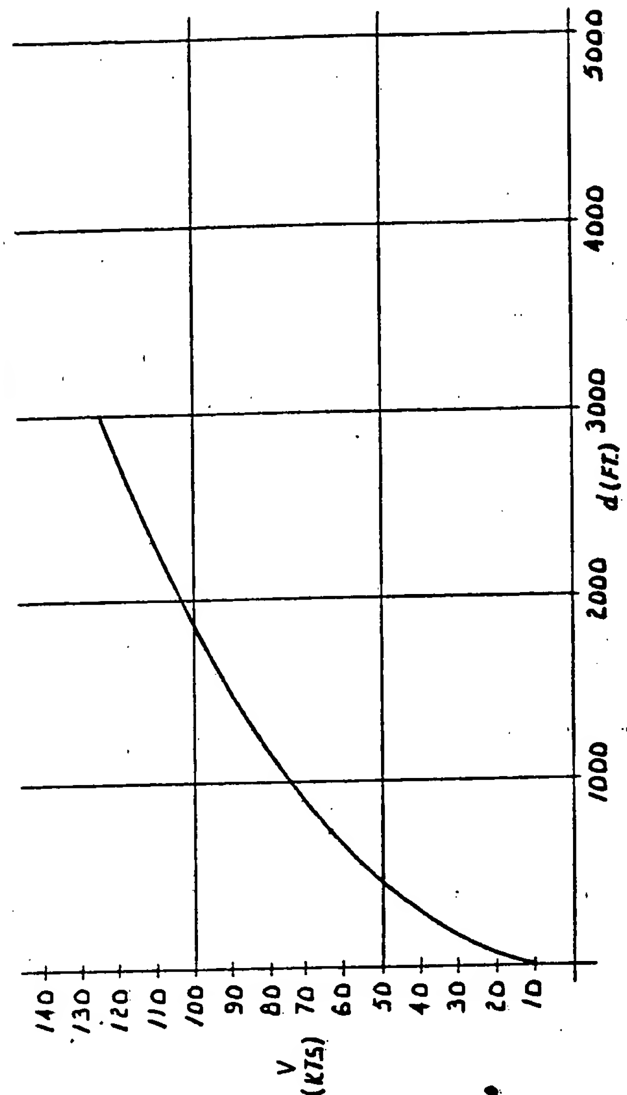

Fig. 3.

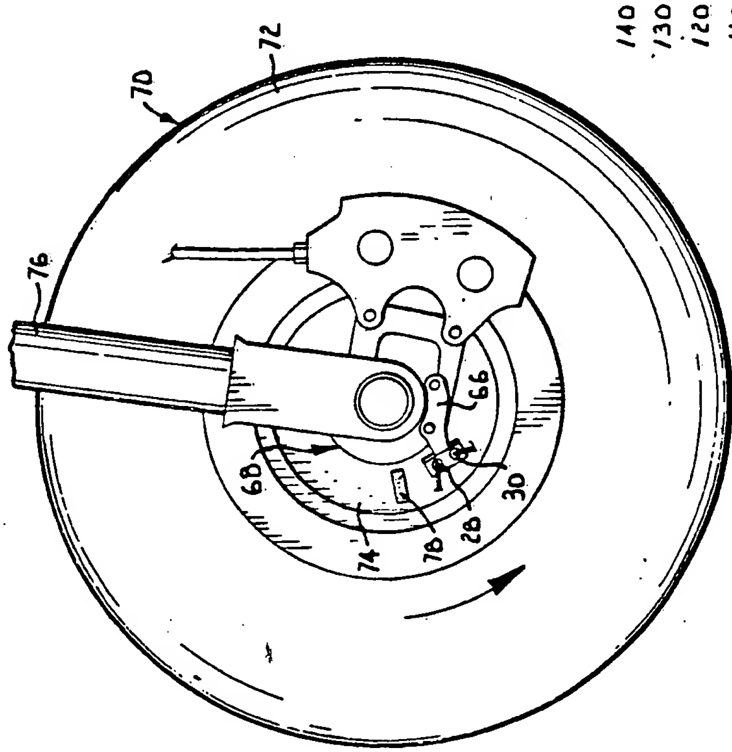

Fig. 1.

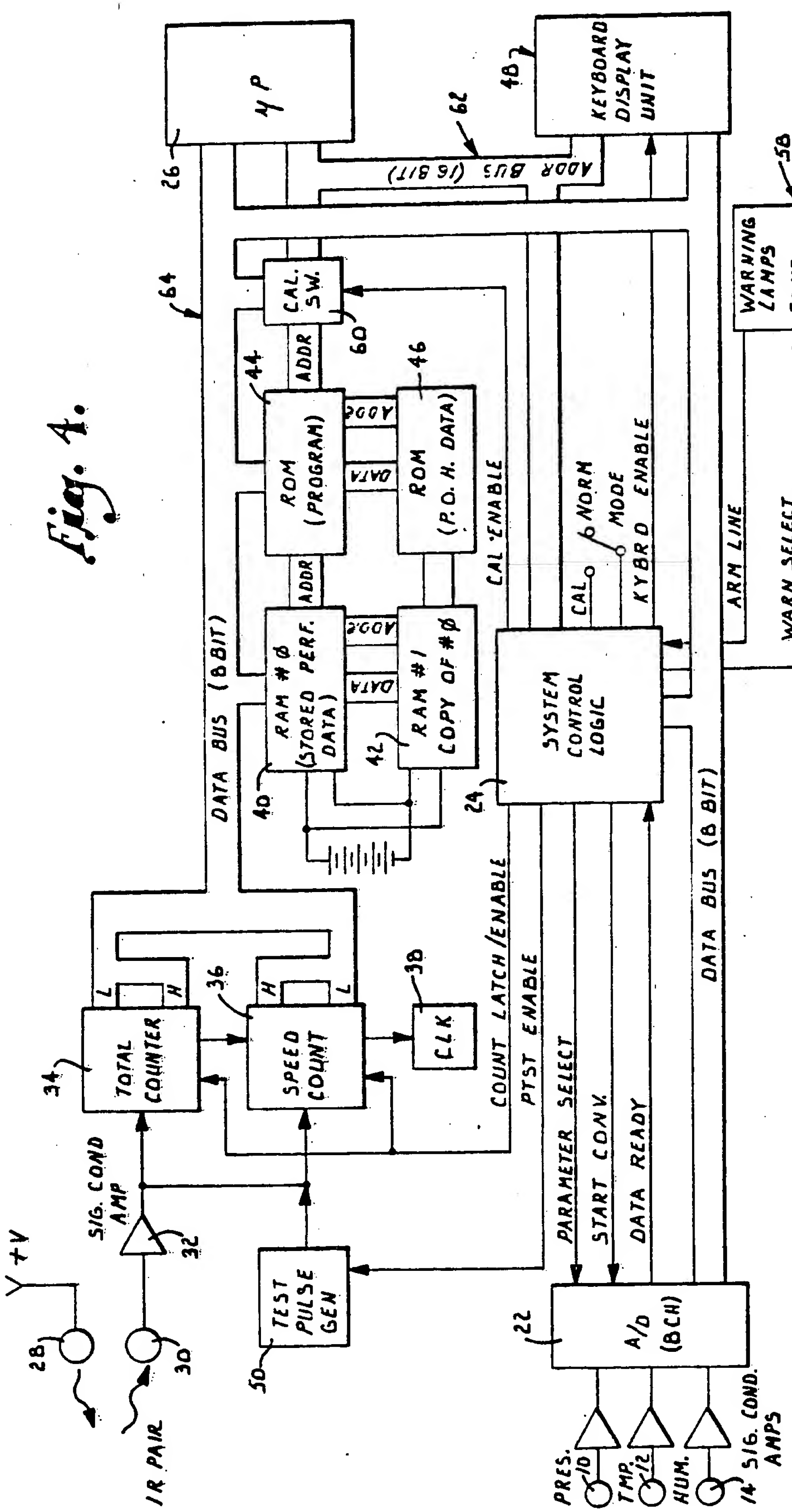
μP
26
KEYBOARD DISPLAY UNIT
48
62
ADDR BUS (16 BIT)
64
DATA BUS (8 BIT)
CAL. SW.
60
ADDR
44
46
ROM (PROGRAM)
ROM (P.O.H. DATA)
ADDR
DATA
CAL ENABLE
RAM #0 (STORED PERF. DATA)
RAM #1 COPY OF #0
40
42
SYSTEM CONTROL LOGIC
24
CAL
NORM
MODE
KYBRD ENABLE
ARM LINE
WARN SELECT
WARNING LAMPS TONE ARMING
58
TOTAL COUNTER
SPEED COUNT
CLK
34
36
38
L
H
COUNT LATCH/ENABLE
PTST ENABLE
PARAMETER SELECT
START CONV.
DATA READY
DATA BUS (8 BIT)
SIG. COND AMP
32
+V
28
30
IR PAIR
TEST PULSE GEN
50
A/D (BCH)
22
PRES.
10
TMP.
12
HUM.
14
SIG. COND. AMPS

Fig. 4.

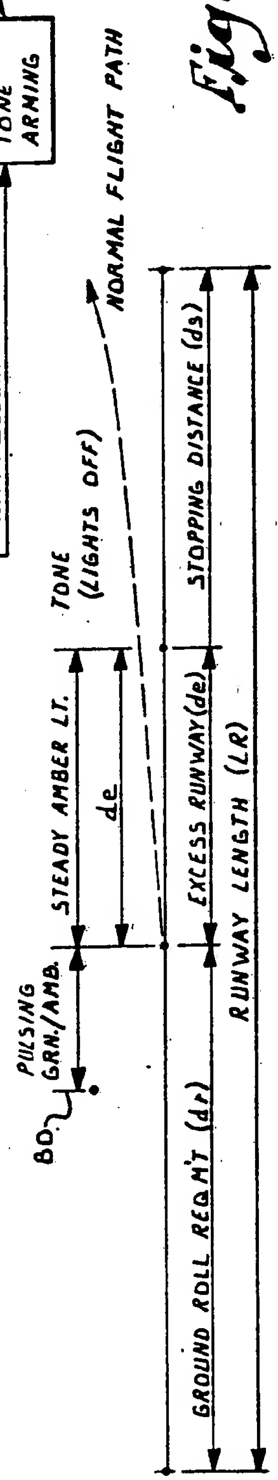
NORMAL FLIGHT PATH
TONE (LIGHTS OFF)
STEADY AMBER LT.
de
PULSING GRN./AMB.
80
STOPPING DISTANCE (ds)
EXCESS RUNWAY (de)
RUNWAY LENGTH (LR)
GROUND ROLL REQ'M'T (dr)

Fig. 5.

INTERNATIONAL SEARCH REPORT

International Application No PCT/US84/01430

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

INT. CL.[3] G06F 15/50
U.S. CL. 364/427 ; 340/959 ; 73/178T

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U. S.	364/427, 439, 440, 561, 565, 571 340/959 73/178T

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
X	U.S.A. 4,122,522, (Smith) 24 October 1978	1-6,10-11, 15-17
X	U.S.A. 4,251,868, (Aron et al) 17 February 1981	1-6,10-11, 15-17
P,X	U.S.A. 4,454,582, (Cleary et al) 12 June 1984	1-6,10-11, 15-17
Y	U.S.A. 3,368,065, (Kendall) 06 February 1968	7-9,12-14
Y	U.S.A. 4,167,699, (Baker) 11 September 1979	18

* Special categories of cited documents: [15]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
13 December 1984	26 DEC 1984
International Searching Authority [1]	**Signature of Authorized Officer [20]**
ISA/US	Gary Chin Gary Chin

Form PCT/ISA/210 (second sheet) (October 1981)